VI.

THE SCIENTIFIC WORK OF THE HOWGATE EXPEDITION.

The scientific work of this preliminary expedition was intrusted to the writer as meteorologist and to Mr. Ludwig Kumlien as naturalist. We were both young, of strong *physique,* and full of zeal for the work.

Professor Loomis, of Yale, and Professor Abbe, of Washington, prepared the meteorological instructions, and Professor Baird, of the Smithsonian, those for the naturalist. These instructions were followed as closely as the circumstances of the situation and the outfit permitted.

It is difficult for a single observer to carry on a system of hourly observations in meteorology day and night for a whole year, even in a comfortable observatory in lower latitudes, and very much more difficult within the Arctic and the restricted limits of a small schooner. The same difficulties attend the naturalist, whose observations on land are limited to a few weeks of summer, in which 55° Fahr. marks the maximum of heat (in June), and with an average temperature of not over 37° Fahr., and who does not see the surface of the earth free from snow for even those few weeks.

Mr. Kumlien's collections in entomology comprise four or five species of butterflies or moths, a few beetles, mosquitoes, and house-flies ; and of birds perhaps forty species, chiefly aquatic. It was among the quadrupeds and marine vertebrata that he found his chief reward, and in this field he was greatly assisted by the remarkable sagacity of the native Esquimaux, whose senses, by long training, enable them to detect the spoors of animals and other indications of their presence in those snow-clad regions, which the hunter from lower latitudes would disregard.

With better equipment and a more numerous staff, the exploration of Kennedy Lake—a large body of fresh water, near which the Florence wintered—might have been undertaken. This lake is almost wholly unknown to science, and there is no doubt that it will yield rich results to the future explorer.

On account of the limited space and equipment of the Florence, many physical phenomena were of necessity unobserved, such as the polarization of the atmosphere, the spectra of the aurora, the actinic force of the sun's rays during the long reign of the "midnight sun," etc., etc. All these and other problems, physical, chemical, vital, astronomical, and meteorological, must be considered and provided for in the complete outfit of the proposed Arctic colony on the shore of Lady Franklin's Bay. Many of these problems can never be so well solved as by a thoroughly equipped party resident for a sufficient time within the Arctic as contemplated in the colonization plan.

The following brief abstract will show what was accomplished by the meteorologist. The position of the observatory was determined by the averages of sextant observations made on April 12 and May 24, 1878, as being in latitude 66° 13′ 45″ north, longitude 67° 18′ 39″ west.

This is the position of Annanatook, the Esquimau name of a collection of small islands on the western coast of Cumberland Gulf, where the Florence wintered. This determination of position differs from that given on published maps. But those who are acquainted with the gulf—as the whalers, for example—say the map is incorrect. There is no record of any other observations for this station except those by the writer. On the northeast of these islands rises a range of high, snow-capped hills ; the western horizon is bounded by a chain of low hills ; southeast is open water ; and northwest, as far as the eye can reach, are seen only small, rocky islands dotting the surface of the sea. The surface of the Annanatook Islands is naked rock, save only in the valleys and rocky crevices, where a little soil has gathered, and a few grasses, flowering plants, and mosses grow. Dwarf willows, resembling blackberry-vines, run along the ground, and diminutive beeches lie hidden, buried in the moss, while the rocks are covered with lichens.

The highest hill at Annanatook, by barometer, measured only two hundred and ninety-nine feet in height, two others being one hundred and ninety-eight and eighty-four feet respectively. But on the eastern mainland one hill, by no means the highest, measured fourteen hundred and sixty-six feet, an elevation corresponding very closely to the snow-line in summer at this point. Patches of snow were observed at this elevation on other hills behind the one here measured rising to the estimated elevation of from two to three thousand feet.

Barometer.—The monthly averages of the barometer at Annanatook show a gradual increase of the atmospheric pressure from December, when it is at minimum, until May and June, when it is the greatest. It then falls pretty uniformly to its initial point in December and January, as will be seen by comparing the means in the following condensed table. The lowest pressure observed was 28·89 in December, and the highest recorded was 30·47 inches, a difference of 1·58 inch.

The mean hourly difference was only ·005 inch; the greatest was June 9th, ·025 inch.

Northwest winds accompanied the highest and southerly winds the lowest barometer.

Table of Barometric Means observed at Annanatook for the Several Months of 1878, *corrected for Temperature.*—O. T. SHERMAN, *Observer.*

MONTHS.	7 A. M.	4 P. M.	11 P. M.	Means.
January	29·598	29·594	29·594	29·595
February	29·736	29·716	29·719	29·724
March	29·830	29·823	29·815	29·823
April	29·995	29·984	29·999	29·993
May	29·960	29·964	29·959	29·961
June	29·786	29·785	29·799	29·790
July	29·757	29·748	......	29·753
August	......	......	......	......
September	29·712	29·698	......	29·705
October	29·735	29·751	......	29·743
November	29·770	29·775	......	29·773
December	29·571	29·575	......	29·573

Temperature.—It is often remarked that it is the extremes of temperature rather than its averages which decide the character of a climate. It is undoubtedly true that extremes are the limiting conditions of distribution of species if not of life in both animals and plants, but especially in the latter. At Annanatook we were too far south to meet the extreme of Arctic cold, the lowest temperature observed being — 52·5° by the ship's thermometer, and — 49·5° by the station thermometer on shore in January. But in the same month the temperature rose to 21·5° Fahr. Sudden changes of temperature occur in these high latitudes as well as in lower : for example, on the 5th of May there was a rise in the thermometer of 11° F. in an hour, and encouraged perhaps by such a promise of warm weather a fly was found on the ice on the 8th of the same month, and by the 24th of May crowsfoot was in bud. Yet in May the temperature fell to — 8° Fahr. How relative our notions of temperature are is evident from the fact that in Disco Bay the ladies of the Danish officers, resident there, find use for their parasols against the fervid heat when the thermometer reads 35° to 40° Fahr. ! On the day in January when we had the lowest temperature, coming on board the Florence I was met by the cabin-boy, bareheaded on deck, rejoicing in the fine warm day, which he guessed might be about + 10°. It was by record — 49·5 ! This confirms Dr. Kane's statement that they felt oppressed by heat when the temperature rose from — 60° to zero. We print a condensed tabular statement of the highest, lowest, and mean temperatures observed at Annanatook :

MONTHS.	Highest.	Lowest.	Mean.	MONTHS.	Highest.	Lowest.	Mean.
January....	21·5	— 49 5	— 17·6	July	52·8	34·0	40·0
February..	11·5	— 42·0	— 18·0	August...	....	....	....
March.....	35·8	— 45·0	— 13·7	September	47·0	28·0	37·0
April......	35·4	— 14·0	10·4	October...	35·2	4·0	22·8
May.......	48·5	— 8·0	25·6	November.	28·0	— 10·0	7·3
June......	55·3	18·0	34·9	December.	21·5	— 41·0	— 11·8

Thus it appears that in seven months of the year the temperature fell below zero, and for four months the mean was under — 10°. In the three summer months alone is the mean above freezing, the maximum summer temperature (55·3°) being in June (August having no record).

A limited number of observations only were made with the black-bulbed thermometer showing the effect of absorption of solar radiation. The results are presented in the following table :

Table showing the Difference of Temperature due to Absorption of Solar Heat by a Thermometer-Bulb blackened with India Ink and protected from Wind, at Annanatook.

DATE.	Mean time.	Black bulb.	Air.	Difference.
January 31	Noon.	− 13°	− 20·3°	7·3°
February 1	12·15	− 10	− 21·4	11·4
" 1	2·15	− 15	− 22·5	7·5
" 1	3·15	− 23	− 23·5	0·5
" 2	12·15	− 10·5	− 20	9·5
" 2	1·15	− 12·8	− 18	5·2
" 4	12·15	− 9·0	− 18·2	9·2
" 4	1·15	− 10·0	− 17·5	7·5
March 6	11·15	+ 46	− 27·5	73·5
" 6	12·15	+ 36	− 34·5	70·5
" 6	2·15	+ 26	− 33	59·6
" 7	10·15	+ 30	− 26	56·0
" 7	11·15	+ 40	− 28·5	68·5
" 7	12·15	+ 40	− 28·6	68·5
" 7	2·15	+ 27	− 27	54·0

The differences noted in these observations are remarkable, and render the multiplication of similar observations hereafter very desirable with an instrument properly constructed for the purpose.

Temperature of the Human Body.—A few observations appear to show that the normal temperature of the human body, 98·4° Fahr., is very slightly if at all changed by the climate. Thus, February 28th the temperature of two of the corps was respectively 98·2° and 98·4°. March 4th, a native was 98·4°. "This fellow has come this morning on a sledge-ride, and has been working in the snow, building a house, at a temperature of — 25° Fahr." Three Esquimau children, March 8th, had a temperature of 98·4°, and a man 98·4°. It is desirable that these observations should be extended. The blood is known to become abnormally heated by intense summer weather, rising even to 99·7°, and by prolonged exposure to cold baths the human body has been cooled with safety to 88° Fahr., but not lower, showing an extreme range of observed temperature of 11·7° Fahr.*

Sea-Water Temperature.—The surface-water at Annanatook was in January, 28·2°; February, at surface, 29°; at 18 feet depth, 29·1°–29·3°; in May, 29° at surface, 29·5° at 18 feet depth; in June, 31·8° at surface, and 31·1° at 18 feet depth; in July, 38·2° at surface, and 22·4° at 18 feet depth; these are means.

* Dr. B. F. Craig, "Variations in the Temperature of the Human Body," "American Journal of Science" (3), ii., 330.

In September the surface in the early days of the month was 37° ; in the latter days, 33° ; and for the mean, 35°. In October it was 30·01° ; in November, 28·8° ; and in December, 27·8°. The highest temperature observed in the sea, at Annanatook, was 39·4°, and the lowest, 26·7°. At Disco, in August, the surface of the sea was 44·1°.

Day and Night.—There are two circumstances influencing the Arctic night by way of compensation, not often mentioned, namely, the great length of the twilight, and the power of the moon to temper the darkness. During winter the moon has her highest north declination, and remains above the horizon for some days continuously, giving light enough for the traveler, and greatly alleviating the gloom of this oppressive season. All Arctic travelers agree in the depressing effect of the darkness. Work at other times pleasant then becomes most irksome. As showing the approach and departure of night, it is noted in my journal :

"*November 7th.*—Observation at four taken by lamplight."

"*March 14th.*—The first day we were inconvenienced by the glare of the sun's reflected light."

"*April 26th.*—Read common pica type with ease at midnight."

Table of Mean Length of Day and Night, and of Twilight, at Annanatook.

MONTHS.	Day.	Night.	Twilight.	MONTHS.	Day.	Night.	Twilight.
	h. m.	h. m.	h. m.		h. m.	h. m.	h. m.
October 16...	9 28	8 24	6 8	April 16.....	15 56	....	8 4
November 16.	5 44	11 28	6 48	May 16......	21 16	....	2 44
December 16.	2 32	12 56	8 32	June 16.....	24 00	....	....
January 16...	4 37	12 01	7 22	July 16......	21 02	....	2 58
February 16..	8 14	9 36	6 10	August 16....	16 48	....	7 12
March 16....	11 48	5 58	6 14	September 16.	13 00	3 20	7 40

Aurora.—The aurora is emphatically a polar phenomenon, and all who have wintered in these boreal regions dwell on the wonders of this polar light.

The records show that one hundred auroral exhibitions were observed at Annanatook from November, 1877, to August, 1878, distributed as follows, viz. : twenty in January, sixteen in February, twelve in March, seventeen in April, and two in May. After the first few days of May it was too light to observe the aurora, and so continued until the close of August, when two were observed—in November ten, and in December twenty-one.

The most brilliant auroras were seen in January and April.

The colors observed were usually pale blue, sometimes very pale green, rarely straw yellow, and once only, rose, at the base. The light from the aurora was sufficient to guide the traveler in his path. Twice I recovered my lost way by its aid, and once its brilliancy was sufficient to cast a glare on the water like that of the moon. It occasionally affected the ordinary compass-needle, as on the 29th of August when the ship's compass could not be used while the auroral display lasted. Doubtless if our magnetic instruments had been more complete we would have observed more frequent magnetic disturbances. The number of auroras observed is larger than could have been expected at this position. The usual appearance of the polar light as seen at Annanatook is as follows: On the approach of evening after a clear day, a dim, haze-like bank appeared along the south-southeast horizon, above which could be detected a faint line of bluish light. About nine o'clock this line began to show some motion, the signal of the grand display which rapidly followed. Arches two or three degrees in breadth commenced to shoot upward toward the zenith, following each other in rapid succession, to the number usually of two or three, the highest number observed being six or eight. Sometimes only one arch was seen. The night of January 10th furnished the following record: About 4 A. M. the arches which had remained in quiet glow, without motion for some time, darted up to the zenith, arch after arch following, until at 5.30 there were eight arches in sight. Each of these sprang from one original arch, advancing rather rapidly toward the zenith. After reaching a point a little to the south and east of the zenith each arch halted. Here five of the arches rested, forming one bright nucleus at the junction, the lower portions of the arch extending beyond and seemingly bending it concave toward the north. The zenith meantime remained fixed, as also the base of the arches. Now, on the approach or development of each new arch the others break into streamers, all passing through the bright nucleus already named. Of the three remaining, two are indistinct, to the south and east, and the third has passed the zenith and to the north in a line running through Capella and Gemini, remaining here as a row of streamers. These gradually fade out, and at 6 (A. M.) only one arch is left in the zenith, moving slowly southward, to be soon blended in the advancing dawn.

On the 2d of March, during a fall of snow, one of the clouds was overspread with a faint-yellow light, which later developed, or continued, into an aurora. At other times the margins of clouds are seen lined by a faint-white light, and the activity of the compass indicated the presence of an aurora.

They have in Greenland comparatively few auroras, so that the European inhabitants at Disco seemed incredulous as to the reports of the constant recurrence of this phenomenon in other parts of the Arctic. The number recorded at Annanatook is exceptionally large.

Halo.—One conspicuous halo was observed on the 19th of January. It consisted of a circle of 22° radius with two extraordinary arcs beyond. Through the sun ran a circle of 40° radius, which appeared to rest horizontally. There were no mock moons at that time; but on the 24th of February there was a halo with mock moons.

Snow.—The fresh-fallen snow (December 24th) crackles under foot like glass beads or "dry oats hanging on the stalk." On the 1st of January the snow fell like spiculæ of ice, hardly noticeable save as it gathered on one's clothes and other objects.

The temperature of the snow at surface and below the surface was taken on two occasions with interesting results. Thus, December 25th, the surface of the snow being − 20°, at one foot below it was − 7·5°; at two feet, − 3°; at three feet, − 1°; at four feet, +3°; at five feet, +10°.

January 5th the same observations gave, at one foot below the surface, − 15°; at two feet under, − 9·5°; at three feet, +0·5°; at four feet, +9°; and at five feet, +10°.

These observations explain the comparative comfort of the native snow-houses with walls five feet thick. The precipitation for January was 0·5 inch of water; for February, 0·49; for March, 0·5; for April, 0·77; for May, 1·18; for June, 1·85; for July, 4·18; for August, —; for September, 8·88; for October, 1·07; for November, 1·04; for December, 0·98—total (less August), 21·44, or, for the twelve months, about 28 inches, probably, estimating August as a mean between July and September.

Ice—Freezing of the Sea.—October 9th, ice appeared in the fiord. October 12th, crystals of ice came up with the deep-sea thermometer. October 29th, ice is reported in the lower gulf. November 10th, new ice formed in the harbor, and afforded passage to the ship. November 27th, the ice in the harbor would hardly bear passing. May 10th, the ice at the schooner was very rotten, and quickly broken through by a cask thrown overboard. May 19th, the ice decayed very rapidly. May 28th, the Esquimaux hunters report the ice as very treacherous. June 4–5th, on the breaking up of the shore ice the passage to the ship became hardly passable. June 8th, the ice near the ship, eight inches thick two days since, would not bear a man's weight. June 9th, ice formed on the salt water near the edges of the firm ice—probably fresh-water ice from regelation.

Winds.—Happily during the winter months the winds are very light in the Arctic. A much less degree of cold would become intolerable with a high wind. The change from a westerly to a southerly wind produces a marked change in the atmosphere, and becomes most depressing to those exposed to its influence. The year's observations on the wind are condensed in the following

Wind Table.

MONTHS.	MEAN HOURLY VELOCITY.			Prevailing current.	Highest velocity per month.
	8 A. M.	5 P. M.	Midnight, 12.		
January	4·1	4·3	4·1	West.	36·3 miles.
February	3·9	4·0	3·0	West.	24·1 "
March...................	4·4	5·1	4·8	West.	48·0 "
April...................	6·4	8·1	5·7	West.	35·7 "
May.....................	5·6	8·1	5·0	Southeast.	26·9 "
June....................	8·1	12·1	....	West.	33·9 "
July....................	17·0	21·0	11·0	Southeast.	25·0 "
August..................	....	....	....	....	....
September...............	5·2	5·9	....	Northwest.	35·0 "
October.................	8·2	11·7	....	Northwest.	29·5 "
November................	11·4	15·2	....	West.	42·8 "
December................	8·98	8·4	9·49	West.	31·8 "

Clouds.—Taking the mean of the year, about 68 parts in the 100 of the sky at this station were overcast. November, December, and January were the least cloudy months; from May to October was the period of cloud, and in September was the maximum, 89 parts in 100 of the sky being overcast. The stratus was by far the most common cloud. It was found difficult to distinguish between the stratus and the cirro-stratus. The cirrus was unlike the form so distinguished in our latitudes. In place of the so-called "mares' tails" the cirrus clouds of the Arctic seemed to repose on beds inclined to the horizon at an angle of about 40–55° from southeast to 120° northwest, the impression on the mind of the observer being that the cloud-mass thus stratified always moved from some westerly point. Out of forty-two recorded cases the movement in only two instances was from an easterly point, and one of these is doubtful. The Esquimaux say that high clouds moving from the east indicate fair weather. Many facts go to show the sagacity of these people with regard to natural phenomena.

The cumulus or "thunder-head," so common as a summer cloud in lower latitudes, was not observed. Cumulo-strata do occur, however, as has been noticed by another voyager.

Table of the Amount of Cloudiness observed at Annanatook.

MONTHS.	HOURS OF OBSERVATION.				MONTHS.	HOURS OF OBSERVATION.			
	7.	4.	11.	Mean.		7.	4.	11.	Mean.
January.....	$\frac{51}{100}$	$\frac{43}{100}$	$\frac{39}{100}$	$\frac{44}{100}$	July.......	$\frac{80}{100}$	$\frac{80}{100}$	$\frac{70}{100}$	$\frac{77}{100}$
February....	$\frac{63}{100}$	$\frac{73}{100}$	$\frac{59}{100}$	$\frac{65}{100}$	August.....	...	...	...	...
March.......	$\frac{65}{100}$	$\frac{62}{100}$	$\frac{58}{100}$	$\frac{62}{100}$	September..	$\frac{91}{100}$	$\frac{87}{100}$	...	$\frac{89}{100}$
April.......	$\frac{78}{100}$	$\frac{61}{100}$	$\frac{47}{100}$	$\frac{60}{100}$	October.....	$\frac{79}{100}$	$\frac{80}{100}$	...	$\frac{80}{100}$
May.........	$\frac{70}{100}$	$\frac{77}{100}$	$\frac{80}{100}$	$\frac{76}{100}$	November...	$\frac{82}{100}$	$\frac{71}{100}$	$\frac{59}{100}$	$\frac{71}{100}$
June........	$\frac{79}{100}$	$\frac{75}{100}$	$\frac{84}{100}$	$\frac{79}{100}$	December...	$\frac{37}{100}$	$\frac{58}{100}$	$\frac{53}{100}$	$\frac{49}{100}$

The average cloudiness of the year in New England is about 53 parts in 100, while for Great Britain it rises to $\frac{70}{100}$, or a little more than the average within the Arctic at this station.

Other Observations.—Systematic observations were also conducted, as far as circumstances permitted, on several other lines of investigation, such as determination of the density of sea-water by the balance, upon ocean currents, on sediments obtained from melted snow and ice, upon tides, etc., etc.

The tidal records, when reduced, will, it is believed, give valuable data for comparison with the work of other observers in this line, no observations in this part of the Arctic having been hitherto made. The rise and fall of the spring tide at Annanatook was twenty-four feet and six inches; of the neap tide, seven feet. Establishment $4^h\ 52^m$, and the age of the tide $54^h\ 8^m$. From January 13th to April 26th the record is nearly complete, and for forty consecutive days, ending in April, it was uninterrupted. The writer desires to acknowledge here the valuable assistance rendered him in the preparation of this article by Professor B. Silliman, of Yale College.

ORRAY TAFT SHERMAN.